

HORIZON



Signs of Life

Transcript of the programme transmitted
11th June 1990



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Signs of Life is an exploration of the new field of Artificial Life, a provocative and adventurous line of new research that aims to reveal nothing less than the secret of life. As explained early on in the film by one of the founders of the field, Danny Hillis, 'Many scientists would like to believe that you start out with almost nothing and somehow if you just mix together the right soup something like life will emerge... And in a sense what we're doing is not so different from that. But instead of mixing together chemicals, we're mixing together programs and bits of information and the soup is the soup that lives inside a computer'.

Artificial life researchers are trying to understand the secret of life by turning on its head the traditional approach of biologists. Instead of analysing living things by taking them apart, they are using computers to simulate simple organisms capable of multiplying and evolving autonomously. The programme includes many startling and beautiful computer simulations that are, their creators claim, 'signs of life'.

Despite being in its infancy, artificial life has even shown that life may be far more widespread than we assume it to be - that artificial life-forms may be colonising our computers, our telephone networks, even our brains. Computer viruses are, perhaps, the first signs of lifeforms - ones that inhabit computer networks rather than the biological realm.

And if the simple roots of life can be revealed, the belief is that eventually scientists will be able to create living beings that could enjoy an independent existence - much as Dr Frankenstein's doomed creature did. These life-forms will be confined, at least initially, to a computer environment.

'As our computer networks get more and more complex', warns the artificial life pioneer Chris Langton, '...we have implemented in some sense a very complicated, low-level physics in which these phenomena can emerge naturally, whether we create them or not.'

John Wyver
Producer

DANNY HILLIS (*Founding Scientist, Thinking Machines Corporation*):

Many scientists would like to believe that you can start out with almost nothing and somehow if you just mix together the right soup, something like life will emerge. I think that's been a dream of science since probably pre-history, certainly pre-science. The alchemist's dream was that you mix together the right combinations of elements and suddenly a creature will emerge out of it and talk with you. In a sense what we're doing is not so different from that, but instead of mixing together chemicals, we're mixing together programmes and bits of information and the soup is a soup that lives inside a computer, but essentially that's what we're hoping for: we're hoping that we put in something relatively simple and what we get out is very complicated and interesting. That's really the essence of artificial life.

NARRATOR (SUSAN RAE):

Biology has revealed much about the way living things work, but life itself, the mysterious quality that separates the living from the dead, has remained a secret, a secret as well kept in the age of science as it was in the age of alchemy. Researchers now believe that by putting life together, rather than taking it apart, by creating artificial life, they may have revealed that secret. They also believe that life is far more widespread than we assume it to be. Parasitical life forms could be colonising our computers, our telephone networks, even our brains.

Life seems to break the most basic assumption of science, that the laws of nature are blind. Living things grow as if following some grand design: simple shapeless lumps of material magically turn themselves into complex organisms. They adapt to, and alter, their environment; they reproduce themselves; they move without being pushed. Does this mean that life is somehow beyond the laws of nature? For some, that is the only possible explanation.

EXTRACT FROM "FRANKENSTEIN" BY MARY SHELLEY:

It was on a dreary night of November that I beheld the accomplishment of my toils. With an anxiety that almost amounted to agony, I collected the instruments of life around me that I might infuse a spark of being into the lifeless thing that lay at my feet. By the

glimmer of the half-extinguished light I saw the dull yellow eye of the creature open. It breathed hard and convulsive motion agitated its arms.

CHRIS LANGTON (*Los Alamos National Laboratory*):

Vitalists believe that life is a kind of a fifth force, a quintessence that is imposed upon the physical material of an organism that gives it its life and vitality, that therefore there is an organising principle to the matter of life that is imposed from without and not part of the physical universe.

NARRATOR:

For most scientists, vitalism will not do because it puts nature beyond their reach. They prefer to look at life as a machine, one that obeys the same laws of mechanics as any other machine, only differing in the degree of its complexity. If a machine as complex as a creature could be built, it would be just as alive.

Jacques de Vaucanson's celebrated duck which boasted over 400 moving parts was one of the first attempts to build such a machine. Sadly, the duck did not survive. Even artificial life forms are mortal but, as a replica later demonstrated, it could raise quite a flap:

EXTRACT FROM "DAS FREIE WORT":

No sooner has the duck's lord and master filled the dish with oat-meal porridge than our famished friend plunges his beak deep into it, showing his satisfaction by some characteristic movements of the tail. Most astonishing of all are the contractions of the bird's body clearly showing that his stomach is a little upset. After a few movements, we are convinced in the most concrete manner that the brave little bird has overcome his internal difficulties. The smell which now spreads to the room becomes almost unbearable.

NARRATOR:

Since then attitudes, as well as technology, have become more refined with inventors concentrating on reproducing intelligence rather than flatulence.

From its earliest days the computer was treated as a mechanical brain. It seemed natural to use it to reproduce intelligent behaviour in robots, but the result, however intelligent it may have appeared, still wasn't life. All such machines could do was mimic primitive life-like behaviour.

John von Neumann, a pioneer of computing, tried a different tack. One of the defining characteristics of living things is their ability to self-reproduce. He wondered if a machine could do the same. Being a mathematician, von Neumann didn't try to construct such a machine. All he did was prove that it was a possibility.

COMMENTARY ON ARCHIVE FILM ("AUTOMATIC MECHANIC SELF REPLICATION"):

The experiments shown in this film set out to solve the problem first clearly stated by the mathematician von Neumann. Can a machine be constructed which can automatically make another exactly like itself?

NARRATOR:

In the late 1950s a British scientist, Lionel Penrose, and his son Roger decided to put von Neumann's theories to the test.

ROGER PENROSE (*Professor of Mathematics, University of Oxford*):

Well my father worked in human genetics and he'd always been very intrigued by the question of life and consciousness as well, but being somebody who was interested in mathematical games and models and things like that, I think he always liked to reduce things to things he could play around with and this very much rubbed off on me. There was an occasion when the family went to Switzerland for a holiday, I think to visit my grandmother who lived there, and we started talking about whether you could build something, a very simple mechanism, which would reproduce itself. Out of this conversation evolved this first mechanism which consisted of pieces that you had in a track and shook up. A pair of them would link together in one way and then cause others to link the same way, or would link in another way and that would cause others to link in a second way. We felt this did satisfy the conditions of an object which could reproduce itself, it had that aspect of life already there

in a very simple structure.

NARRATOR:

The blocks that evolved from that early conversation could not have been more basic, but that was their beauty. Until then, everyone had assumed that self-reproduction was extremely complicated, even miraculous. Lionel Penrose had shown that it could be achieved using nothing more exotic than a few pieces of plywood.

FILM COMMENTARY (FROM "AUTOMATIC MECHANIC SELF REPLICATION") :

These pieces are neutral to one another and if shaken together so that they collide, they do not join up. However, when a two-piece complex or seed is present, it absorbs them as food and reproduces itself.

ROGER PENROSE:

In his later models he produced very elaborate structures which had this kind of double-strand thing. You'd have a long chain of these things and then you'd build a double-chain and then another one and you'd feed some more, and they would split in the middle and come apart like that, but it was quite hard to make them do that.

NARRATOR:

A strikingly similar mechanism had recently been discovered in nature: DNA. Like Penrose's blocks, DNA forms chains of components, a genetic code. When it splits apart, it acts as a key to assembling two identical copies. So it was first proved that self-reproduction, and therefore perhaps life itself, is a mechanism independent of biology. It's how the mechanism works that matters, not what it's made of. Theoretically, it would work just as well built out of plywood as protoplasm.

RICHARD DAWKINS (*Reader in Zoology, University of Oxford*):

There's nothing special about life in terms of the substance that it's made of. There's nothing in the sort of Victorian idea of life as a pulsating, throbbing, warm, glowing substance called protoplasm.

Life is just made of molecules like everything else. The only thing that makes it living is complexity of information, so if you reproduce the complexity of information in a different medium, not using living cells but, say, using a computer, then you would have in principle the same kind of life.

NARRATOR:

The discovery of the computer was as important to artificial life as the discovery of the microscope was to biology. It provided a way of seeing things that simply could not be seen before, revealing a world too abstract, too mathematical, even to imagine.

RUDY RUCKER (*Professor of Mathematics, San Jose University*):

Mathematics is really a new golden age that's come with starting to use computers. We have fractals, we have chaotic systems, strange attractors, cellular automata and artificial life. We have all these wonderful new structures that would be really impossible for us to have even talked about 20 years ago without the computational power. The computer serves as almost like a new observing instrument. One of the cellular automata workers I talked to a couple of years ago said he felt like Loewenhoek with the microscope. There are all these new worlds that we can look into and what we're finding is many of these things, although they're defined with a dry mathematical formalism, have the sort of juicy realistic look of nature.

NARRATOR:

The computer has provided a way of capturing a characteristic of nature that science had previously missed. Scientists call it non-linearity. To us, it's the untidy irregular behaviour that makes it natural.

DANNY HILLIS:

Many times when we have a system, very simple objects, for example molecules in a fluid, the behaviour of all of them together is somehow very much more complicated, so the whirlpools that happen when a stream flows over a rock are somehow the consequence of the inner action of these little molecules bumping into each

other. Scientists really don't understand the connection between those two things in any great detail. That's what we call an emergent behaviour of the system where simple, local rules create very complicated global behaviour.

CHRIS LANGTON:

One of the things that science has stumbled over and been forced to face in the last two decades, especially the last decade, is that science has always expected that underlying all this complicated behaviour, at the level at which we see nature, would be very complicated things going on amongst the atoms and the molecules, but what's surprised us is that when we create these extremely simple physics and extremely simple universes, we get the same level of complexity on the large-scale. The hope is that life, and other complicated physical phenomena, similarly have simple roots instead of complicated roots, which I think was the assumption for a long time.

NARRATOR:

The aim of artificial life is to discover these simple roots and, through them, the secret of life itself. In theory, if the roots could be found, then so too could the means of reproducing living things.

The search for these simple roots began on the floor. In the late 60s the British mathematician, John Conway, invented a game, one that was so simple he initially worked out the rules by moving dinner plates around a tiled floor. To play the game all you need are some pieces, crockery for example, and a grid - a clean floor will do. There's no skill or judgement involved, just a few basic rules. In each turn the entire board is surveyed to see which squares are occupied and which are empty. When an empty square has three pieces in its eight neighbouring squares, a new piece is put into that square. When the square is occupied and surrounded by two or three pieces, it stays occupied. When a piece is surrounded by more or fewer than two or three pieces, it's removed.

A turn entails working out which pieces should be added and which taken away for the entire board. This simple process is then repeated over and over again.

Certain terms are used in the game: you think of the board as a

universe; the pieces are cells; and each successive turn is a generation.

Played at normal speed, nothing much happens, but play it on a computer which can work out each move in a fraction of a second and strange patterns begin to appear.

At first, the game seemed to be no more than a mathematical diversion. However, Conway had given it the provocative name "The Game of Life". This was sufficient to arouse the curiosity of obsessional computer programmers. One of them, Bill Gosper, still devotes nocturnal hours to exploring its possibilities.

BILL GOSPER (*Mathematical Experimenter, Symbolics Inc*):

It's very obsessive: you just shut yourself off and you're in this other space trying to find out what the limits of possibility are: can this happen, can I make it happen, can I prevent it from happening. It's an alternation between being a naturalist and collecting peculiar events and being an engineer, or a physicist and sometimes there's even a little philosophy if you're too tired to do real work.

NARRATOR:

One of the most interesting patterns to emerge from Conway's first experiments was called The Glider. It has just five pieces. If pieces are removed and added according to the game's usual rules, the pattern re-appears every four moves, only shifted to a different position on the board.

The result is a little object that seems to glide quite independently through the life universe.

BILL GOSPER:

Conway saw many patterns that did more exciting things than this, but they always ended up the same way: they threw out a few gliders and they fizzled to a stop. He started out with this very ideal question of whether this particular rule that he had searched for ever led itself to a reaction that didn't fizz out. For instance, a machine that would make gliders for ever, or a giant sort of glider that would fly along leaving permanent debris adding to the population. He

named the first thing a glider gun, the second thing a puffer train, and then he bet the scientific world in the sense of a wager, or a reward, \$50 for anyone who could prove or disprove the existence or non-existence of a glider gun or a puffer train. I actually collected that \$50 somewhere round 1970.

NARRATOR:

This was the prize-winning solution: a pattern that threw out a constant stream of gliders. Conway could never have worked it out manually - he would have needed an area the size of a football pitch and ended up with more plates on the floor than a Greek restaurant. Only by using a computer was the true potential of the game revealed.

BILL GOSPER:

At first it was not clear that the things that could happen in this universe were nearly as complicated as the things that can happen in our universe and subsequently, just by a sequence of small discoveries, just by degrees, it became clear that anything that we can describe can happen in the life world.

NARRATOR:

Including that illusive characteristic of life, self-reproduction. There is a pattern that will reproduce in the same way as natural organisms. It would need a life universe larger than any existing computer could accommodate, but the patterns produced would evolve independently, at least until someone switched off the computer.

BILL GOSPER:

I would expect to see things that most people would agree were somehow alive in realisable life spaces and I think that within our lifetime we might build a life machine large enough to see qualitatively interesting things happen. This sort of stuff is almost at the atomic physics level.

NARRATOR:

The Game of Life is not the only game to produce such startling

results. The mathematician and author, Rudi Rucker, has designed a computer programme he calls "The Cellular Automata Lab". The games it produces are just like the Game of Life, in that the cells are like pieces on a board. The only differences lie in the rules that determine what happens to the pieces, and in the pieces themselves. In the Game of Life there is just one type of piece; in other games there can be hundreds, each one represented by a different colour. It is in these patterns, in their growth and movement, that the first signs of artificial life are to be found.

RUDI RUCKER:

What we see in a cellular automaton is that we can have a simple rule which is defined throughout space and we can start with a very simple initial condition. Perhaps you only turn on two or three cells, then you let the rule run. The cells that are near the turned-on cells get stimulated, they do something, their neighbours are stimulated in turn, and you have a wave of stimulation spreading out and perhaps propagating back and they can generate extremely complicated structures. The attractiveness of this is that it serves as a model of a universe in which we have this whole complicated world evolving from a simple starting seed and a set of rules.

NARRATOR:

Artificial life suggested a need for a whole new approach to the study of living things, one that turned on its head the conventional practice of analysing them in terms of their parts.

CHRIS LANGTON:

Traditional biology has been a very analytic approach and it's been focussing on the material basis of life. This is the way that they've had to get a handle on what life is: you start with a living thing and you start taking it apart and you see what parts it has and how all those parts fit together and try to derive some general principles of the logical organisation of those parts. It's OK up to a point, but you take something apart and you take it apart further and you take it apart further and all of a sudden you don't have life anymore, life sort of slips between your fingers.

DANNY HILLIS:

In a sense what we're working on is an alternate form of biology because it's a sort of might have been biology. One problem with biology is we only have one example of an earth having evolved, so we have to extrapolate and ask which things are just coincidental and which things are fundamental.

We're using the computer to simulate imaginary biological worlds and we say 'what if', and we can do experiments that would really be impractical to do in a real biological system.

NARRATOR:

And it's in a computer like this, the connection machine, that such imaginary worlds are being built. Like the physics and biology, it is used to simulate. It is made up of relatively basic uniform parts, but is hugely complex in the whole. It's not one big computer, but an array of 64,000 smaller ones running simultaneously. Chris Langton has used a connection machine at the Los Alamos National Laboratory to generate what he calls artificial universes. These cover a spectrum of possible alternative laws of physics. His aim is to see whether any can turn disorder into the minimum degree of order of information necessary to life.

CHRIS LANGTON:

OK, we have here an artificial two-dimensional universe that obeys a local physics and this is a random initial configuration of that universe. As time goes on, each piece of this universe is going to change its state depending only on the states of its immediate neighbours in the space. We're going to be altering a temperature-like parameter and we're to start off with very cold universes and work our way up through to very hot universes and observe the kinds of patterns that emerge under each of these temperature regimes. As we do this, we'll see that we go through from universes which essentially freeze up into solids through a melting point where we're going to see very complicated behaviour, all the way up to hot universes which just act like a hot gas.

So first we're going to work with one of these very cold universes and we'll see that when we start the programme it freezes up almost

immediately and now this is frozen up into a very static pattern.

This universe is beyond the melting point into the gas regime. Although there you can make out a few little areas of frozen activity the gas basically breaks into them and little domains crystallise out, but then are immediately re-melted again, so it's primarily dominated by a very gas-like behaviour. But we think that information is just being destroyed too rapidly for there to be the possibility of any long-term emergent development of complicated structures.

OK, again we're starting with a random initial configuration of the universe and we're very close to the vicinity of this melting point between a universe which freezes and a universe which acts like a gas. So we're going to start it running and we'll see that first of all it does tend to settle down in density, the density gets lower and we still have some parts of the universe that are frozen, but we also have these structures which are propagating around, running into each other and running into the static, frozen parts that are breaking them up only to have them re-freeze again somewhere else. So we have a balance here at this particular temperature, we have a balance between a universe which is trying to freeze up and trying to become a gas. This kind of complicated interaction of the frozen and the chaotic regimes could give rise to what we think of as information processing in this space, so this is the domain in the temperature-like spectrum in which we expect to find the capability for processing information that we think was crucial for the origin of life.

NARRATOR:

Imagine then that we are in a universe at this melting point, one poised at the edge of chaos. How would life first emerge? Would it be a stroke of luck, a freak accident, or inevitable? Could it occur anywhere, or would it need the particular chemical brew that was once to be found on Earth?

STUART KAUFFMAN (*Professor of Biochemistry & Physics, Sante Fe Institute*):

One of the kind of hopes that one has in artificial life is to understand the origin of life itself. The most natural thing one would like to do is to abstract the most fundamental properties of chemistry and to try to understand how in the world it might be possible in the

early evolution of life, or in the early evolution of the planet, that life could have emerged spontaneously on this planet.

DOYNE FARMER (*Theoretical Division, Los Alamos National Laboratory*):

We've been working on a model that allows us to start with a homogeneous, boring, primordial soup with nothing but individual things floating around in it and try and find an evolutionary path through which these things can assemble together into more structured and complicated and interesting forms, that could serve as the building blocks for later life forms. Our model is very much based on insight about existing life forms, about the kind of chemistry that goes on inside of contemporary organisms, but the basic principles can actually be applied in a much broader context.

NARRATOR:

There's nothing unique about the Earth's chemistry. The soup from which life may have emerged could have been primordial, it could have been pea and ham. It's not the ingredients that matter, it's the way they mix together.

STUART KAUFFMAN:

Of course you have to feed it something, you have to feed it some simple building blocks out of which it builds itself, but the principles are very general and they, therefore, also offer the thought that the roots to life are very very broad, that they don't depend upon the detailed chemistry on earth, there may be lots of other ways of getting living organisms.

NARRATOR:

Simulating the process that turned the chemistry of the primordial ooze into the bustle of the living biosphere is one of the most enticing prospects for artificial life research. It means that it may one day be possible to exploit, as well as understand, one of the most powerful mechanisms of nature - evolution.

These are artificial ants, foraging for artificial food (*computer image*).

Their genes are simple computer programmes. By merging these

programmes together the ants can be bred. The resulting offspring inherit a combination of their parents' characteristics. An earlier experiment, called Genesis, set each ant a simple task.

DAVID JEFFERSON (*Asst. Professor, Computer Science, University of California, Los Angeles*):

In the Genesis system our goal was to evolve a population of ant-like organisms that could follow an artificial trail in an artificial environment in a way similar to the way natural ants follow natural ant trails.

NARRATOR:

The trail was not an easy one to follow, at least not for the first artificial ants to be set loose on it. Since their genes were randomly mutated, nearly all of them quickly fell by the wayside.

DAVID JEFFERSON:

But a few of them were better able to walk on the trail than most of the others and we took the best ants from that first generation and artificially breed them with one another to create a second generation and we tried all of the second generation ants on the trail. The second generation ants were a little better able, as a whole, to walk the trail, although still not very good and we repeated the same procedure. We took the best ants from the second generation and bred them to create a third generation and tried them all on the trail. We would repeat this procedure, generation after generation, always selecting those ants that performed best in one generation, to breed the entire next generation. This is approximately the way natural evolution works in real populations.

NARRATOR:

The proof that they were simulating a form of real evolution came in the results. These artificial creatures acquired a skill which had formed no part of their original design.

DAVID JEFFERSON:

Because the first generation of ants was entirely random, they had

absolutely no ability at all to walk the trail, there was no bias in favour of being able to walk the trail at all. The point of starting with random ants was to be sure you start with a population that did not have any skill at all in walking the trail and so by 50 or 100 generations later, when the entire population almost could walk the trail, it's clear that the ability to walk the trail came by evolution and by no other means.

NARRATOR:

Such experiments are not just about simulating evolution. They're also aimed at finding ways of using it to solve problems. Coloured dots on the screen represent creatures populating an imaginary world. Danny Hillis, who created this world, has given the creatures one simple purpose in life: to solve a programming problem.

DANNY HILLIS:

What you see here is a population actually evolving while we're watching it, so every one of those dots on the screen represents a little creature that's living in this imaginary world. A brighter coloured creature is a more fit creature. As the creatures evolve, the more fit creatures begin to take over the neighbourhood, so when you see a particular colour disappearing that means that that type of creature is disappearing, so this is a competition between a lot of different computer programmes that are each trying to solve a little puzzle. The ones that solve the puzzle survive the best, and so they reproduce more often and so you'll see them spread across the screen. As we see a certain area begin to expand in the picture, that represents a solution to the puzzle that's more fit than the other solutions.

Of course our simulations miss many of the details of the real biological world and many biologists rightfully say that our conclusions are not necessarily applicable to real biology because, of course, what's going inside the computer is much simpler than what's going on in real biology. If we've somehow capture an essence of what's important in biology in one of our simulations, then it may be that the lessons we learn in our simulations carry over to real biology.

NARRATOR:

But is it life? Roger Penrose is sceptical.

ROGER PENROSE:

I think the important thing about living systems is that they are acting according to the laws of physics in the universe that we have and those laws of physics are very subtle and we don't even understand them all. The things like cellular automata are based on simple procedures which are really not very like the actual laws of physics that govern the universe we live in. I think that you're not really going to get to a profound understanding of things like life without delving much more deeply into the actual physical laws that govern our universe.

RICHARD DAWKINS:

A small part of life can be implemented on the computer. There is nothing fundamentally mysterious. The only thing that's mysterious is the complexity. Don't let's under-estimate that ever. It's exceedingly difficult, it's actually far more mysterious in many ways than the rather silly mysteries that have been erected in the past - I mean religious mysteries and things. The real mysteries of life, how the complexity comes into being, how this enormous complexity works to produce the remarkable phenomena that we see; that's a genuine mystery, it's one that we shall one day solve and in some ways it's more difficult, but because we have the hope of its solution, it's a more constructive approach to mystery than just simply saying this is a mystery, we can't touch it, let's just accept that it is a mystery.

NARRATOR:

And the proof that the mystery is one that could be embraced by computers may have already been demonstrated, as much by accident as by design.

DANNY HILLIS:

The telephone network is a good example of a computer system that has become so complicated that it has emergent behaviour of its own, it has an ecology of its own if you will. The phone network

recently crashed in the United States, a large part of it became inoperative. The reason was an interaction between parts of the system that was never anticipated by people. Each of the individual programmes running in each of the individual switching stations worked just exactly like it was supposed to and yet the behaviour of the system was not what it was supposed to be. That's an example of emergent behaviour and it's an example of a piece of emergent behaviour that was not understood by the designers of the system.

NARRATOR:

No-one is yet suggesting that life can be found in the telephone system, but the network has started to behave in the same volatile way that nature itself behaves and it's in just such an environment that the first signs of artificial life may spontaneously emerge.

DOYNE FARMER:

As computers become more and more prevalent, they become more and more connected together. We form computer networks that serve as a kind of augur for information to propagate through an electronic medium. As that medium becomes more complex, patterns spontaneously emerge that begin to exploit that medium. Computer viruses are one of the most pressing manifestations of this phenomenon.

DANNY HILLIS:

One problem of artificial life that I think a lot of people will become familiar with, whether they want to or not, is computer viruses. This is life in the sense that it's self-replicating, it's a computer programme that copies itself from one computer to another. It's actually a computer programme that lives inside another computer programme; that's why it's called a virus because a virus lives inside another form of life. Now many viruses do nothing but replicate themselves from one computer to another, but other viruses have effects of making the computer sick just like some viruses make humans sick. When we share software, for example if I give you a computer programme that's infected with a virus, then suddenly your computer is infected with that virus, so if you share a programme with someone else, suddenly their computer is infected with that virus. The virus may do something awful like delete all

your files, or may do something sneaky like waiting around until January 1st 1995 and deleting one word in every file. That would cause tremendous problems for our society if something like that happened and in fact it already is causing tremendous problems for us.

NARRATOR:

But are such viruses really alive? Living organisms have certain distinct characteristics. They're free-roaming, they reproduce and mutate, they adapt to and change their environment, they collect together into populations.

DAVID JEFFERSON:

Computer viruses have a lot of these properties. They are free-roaming structures, although they roam throughout computer networks instead of through the rest of nature. They are self-replicating, they can, in principle, replicate with variation, although fortunately they don't do so yet. They have most of the characteristics that we would require of artificial life and it does not seem to me to be an exaggeration to say that computer viruses are an elementary form of artificial life. Yes, I would say they are.

NARRATOR:

And they may not be the only non-biological life forms. There may be others replicating unnoticed on the other side of the universe, or here on Earth.

RICHARD DAWKINS:

On other planets in the universe, I feel sure there are probably other kinds of replicator other than DNA. I suspect that the original replicator on this planet probably was not DNA but we don't know what it was. I think it may be that even now on this planet there are other kinds of things that deserve the title of a replicator.

NARRATOR:

Richard Dawkins has described just such a replicator, which he calls a meme. Like the DNA that makes up our genes, memes can mul-

tiples, mutate and evolve, but unlike DNA they breed not in nature, but in culture, through human communication.

RICHARD DAWKINS:

They're the brain equivalent of a gene, they're things that pass from one brain to another, so if I know a good tune and whistle it and you pick it up and think it's a catchy tune and whistle it and somebody else picks it up, then something has passed from brain to brain to brain to brain which is rather like a gene passing from body to body to body to body and potentially it has the same quality of going on for ever and therefore it has the same property of being subject to natural selection. Now tunes are not particularly interesting examples, but if you take something like a religious idea, say the idea of religious faith, or the idea that says if you give up the faith in which you were brought up you deserve to be killed, then that is a meme which has a certain survival value. If people are afraid that if they announce that they've given up the faith of their fathers and publish books announcing that they've given up the faith of their fathers, if they're then threatened with being killed, then other people may get the message that this is not a thing to be defied, the meme spreads.

NARRATOR:

Hans Moravec also believes that culture, like nature, can support life, but he is prepared to go much further than that.

HANS MORAVEC:

Today and for several thousand years in the past, the amount of information that's passed from generation to generation in cultural form is much larger than the amount that's passed in DNA; there are only about two billion bits in a single human's DNA and only a moderate number of variations of each of the elements there.

NARRATOR:

We can no longer exist purely on the information passed on by our parents through their DNA. In the age of cook chill microwave meals and mortgage protection plans, we cannot rely simply on our bodies and instincts to find us food and shelter. It is cultural infor-

mation that is now essential to survival. Nurture is overtaking nature.

HANS MORAVEC:

As the proportion increases, it becomes reasonable to ask the question, to what extent is the biological minority of this essential information even necessary? Today, of course, it seems ridiculous to think that you could eliminate it completely because the society does require human beings to operate it and without human beings everything would stop, but this is less and less true and in future will be false. The clearest dividing point between when human beings are necessary and when they're unnecessary, is when fully intelligent, mobile robots begin to move around in the world.

These are machines that can do every job that the human being does in society. It would in principle be possible to run the society with only these machines: if the people were to vanish the machines would run factories, make copies of themselves, run the businesses, operate the economy, operate the research labs that produce improved versions of the machines and you could imagine a world where all the information is passed from generation to generation through culture, where DNA is just a memory, perhaps a few volumes in a library.

NARRATOR:

If such a post-biological world, as Moravec calls it, is a possibility, should science hasten its arrival? Haven't bio-technology and genetic engineering already intruded too deeply into the mystery of life?

EXTRACT FROM "FRANKENSTEIN" BY MARY SHELLEY:

The pale student of the unhallowed arts knelt beside the thing it put together. I saw the hideous fantasm of a man stretched out and then, on the working of some powerful engine, show signs of life and stir with an uneasy half-vital motion. Frightful it must be for supremely frightful would be the effect of any human endeavour to mock the stupendous mechanism of the creator of the world.

We are talking about mastering the technology of life and it's going to have every bit as much potential for abuse as it does for use and so we can't ignore our responsibility in this whole field.

I think the most important thing to realise is, as our technology gets more and more complex, as our computer networks get more and more complex, as our machinery gets more and more complex, we have implemented in some sense a very complicated, low-level physics in which these phenomena are going to emerge naturally, whether we create them or not. This pattern of activity is going to start to happen here, whether we create artificial life, or whether life, this evolutionary process which has been very opportunistic in the past, just makes the leap on its own without our active intervention in the process. The point is that we're going to have to understand it, and in order to understand it we're going to have to study it because it's going to happen and knowledge is power.

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January 15th 1990

During the new decade, the paralysed could walk. There could be cures for many more cancers. We will be able to actually see, and possibly treat, the ravages of multiple sclerosis in the living brain. All this will cost a great deal of money. Other techniques, such as prediction of heart disease and even lung cancer could save money. So could major operations through tiny holes in the body. Unless we balance costs and savings to shape medicine in the year 2000, no country will be able to afford treatments for all those in need.

FOOD IRRADIATION: WOULD YOU BUY IT?

January 22nd 1990

For most people the simple answer would be 'no'. Opposition is vocal and effective. There is little support from trade or industry, yet in its Food Safety Bill, the Government proposes to permit this contentious treatment. What is irradiation? What does it do to food? Will it protect us from food poisoning or merely introduce new and as yet unknown dangers? Does it destroy essential nutrients, and if so, how does this compare with other things we do to food? Can the process be detected or adequately controlled? How much do we really know about its safety?

FROM EARTH TO MIRANDA

January 29th 1990

In the outer solar system, five planets and their attendant moons orbit in perpetual twilight. NASA launched the two Voyager spacecraft to explore this region. They returned spectacular images: from Jupiter's huge and swirling great red spot and the violent volcanoes of its small inner moon, Io, through Saturn's dramatic ring system, to Uranus and its five dark moons. One of these, Miranda, has been smashed and reformed many times. Its terrain shows that our universe is more violent than we thought.

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ENCOUNTER WITH NEPTUNE

February 5th 1990

After a 12 year journey, NASA's Voyager II spacecraft arrived at Neptune late last year.

Neptune's weather was unexpectedly active, with 1500 mile-an-hour winds. Even odder was its planet-sized moon Triton. Voyager's images showed lakes of lavatory cleaner frozen hard as steel, and a bright pink polar cap marked with curious black streaks. Something unbelievably strange was happening on Triton. And when NASA's Dr Larry Soderblom uncovered Triton's secret, it was perhaps the greatest surprise of space exploration so far.

GUESS WHAT'S COMING TO DINNER

February 12th 1990

In the next ten years, you'll be eating food created by genetic engineers. Tomatoes that produce a caterpillar poison, crops that glow in the dark - not science-fiction but fact: new foods that contain genes from microbes, animals and foreign plants.

Do we need this genetically engineered food? The technology could be used to make drought resistant crops for the Third World or to help food processors take a penny off a can of tomatoes. It could be used to reduce, or increase, the use of pesticides. So what will it be used to achieve?

And, when it happens, will it cause ecological chaos?

THE FIRST FOURTEEN DAYS

19th February 1990

The last twenty years have seen revolutionary advances in reproductive medicine, for example, the pioneering work by Robert Edwards, which led to the birth of the first 'test-tube baby' Louise Brown. This programme was made to try and inform the public and parliamentary debate on the moral issues raised by these advances, in the light of the forthcoming vote on the Human Fertilisation and Embryology Bill.

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THE 10,000-YEAR TEXT

5th March 1990

Can anyone predict the future for the next 10,000 years? A mass of scientists in the Nevada desert are trying to. America has chosen to bury all its most lethal high-level radioactive waste there, under Yucca Mountain - if scientists can prove that the waste there would cause no more than 1,000 deaths over the next 10,000 years. That means working out the probability of everything that could happen to the mountain, and the surrounding population. No one has ever had to predict 10,000 years into the future. The scientists at Yucca Mountain have had to resort to some strange fortune-tellers - desert rats, and rocks which eat radioactivity - to find out it is possible.

HURRICANE!

12th March 1990

On 6th September 1988, an ageing propeller-driven plane took off to fly into one of the most powerful and dangerous of natural phenomena: the eye of a hurricane. Its task was to track Hurricane Gilbert as it neared Jamaica and stormed on towards the USA. By accurately predicting Gilbert's path, lives and property might be saved. This required a detailed understanding of how the hurricane worked, where its huge energy came from and what influenced its movement. Gilbert became the most powerful hurricane known, and it devastated Jamaica. What was it like inside the eye?

THE BRITANNIC GREENHOUSE

19th March 1990

The fiercest storms for more than a century, the warmest winters and summers since records began: everyone is blaming global warming. Scientists are out measuring roadside grass, bottling greenfly, staining plant roots, counting fish food, pushing rubber tubes into peat bogs and watching mushrooms grow. They're beginning to foresee how wildlife, landscape and nature responds to the changing climate and discover that nature may already be speeding up the greenhouse effect beyond our control.

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THE CHILD MOTHERS

4th June 1990

Sarah (British) is pregnant at 14. Maideline (Cuban) is pregnant at 15. Niki (American) is expecting her second child at 17 and Chrisianne (Ghanaian) is married with a baby in her mid-teens. In some cultures, early pregnancy is encouraged; in others it is so unacceptable that a teenager might choose a dangerous abortion rather than admit pregnancy. Horizon explores the real medical and social effects of teenage motherhood around the world.

MAKING AN HONEST FIVER

6th June 1990. Horizon Special

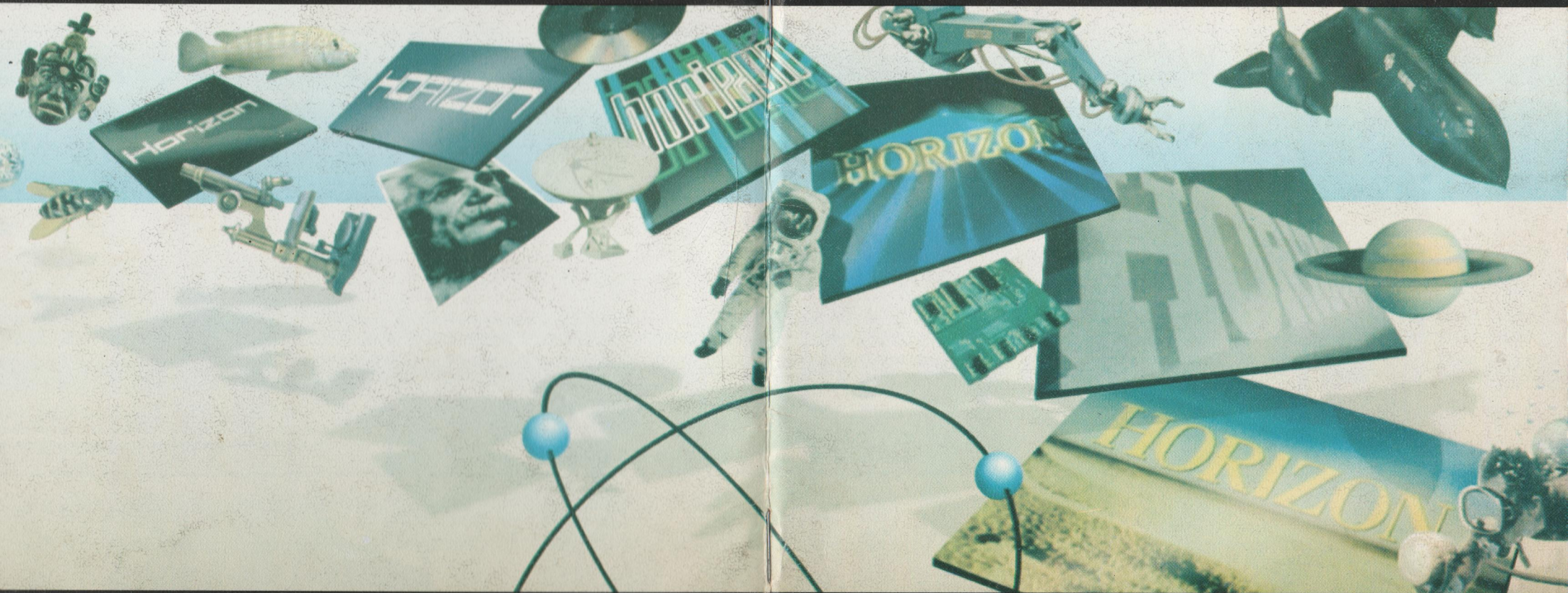
A new £5 note began life on 7th June. This exclusive report followed the development of a new set of banknotes. How do the new notes combat the threat of counterfeits? How will the Queen look 20 years on? Who is on the back of the new notes?

AIDS: A QUEST FOR A CURE

25th June 1990

By the end of the century, 15-20 million people will be infected by the virus leading to Aids. Unless scientists find a cure, all these people will die from the disease. British scientists have now created a compound that stops the Aids virus growing without killing human cells. But it is too early to say if the drug will work on patients. The story of this scientific breakthrough gives hope that one day a cure may be found.

HORIZON



The BBC's longest running science series continues to reflect the forefront of developments in science, medicine and technology. Each transcript is the result of several months of research and brings together the opinions and knowledge of leaders in each subject.

In 1990 **Horizon** is transmitted on Mondays on BBC 2 at 8.10 pm and repeated on Thursdays on BBC 2 at 5.10pm from January to late June.



Signs of Life

Transcript of the programme transmitted
11th June 1990

